NASA TECHNICAL MEMORANDUM NASA TM-75064

ON THE DEVELOPMENT OF EARTH OBSERVATION SATELLITE SYSTEMS

Science and Technology Agency of Japan

Translation of "Chikyu kansoku eisei shisutemu no kaihatsu ni tsuite," Science and Technology Agency of Japan, Tokyo, Japan, Report, July 12, 1977

pp 1-81

(NASA-TM-75064) ON THE DEVELOPMENT OF EARTH OBSERVATION SATELLITE SYSTEMS (National Aeronautics and Space Administration) 38 p HC A03/MF A01 CSCL 22A
N78-18490
Unclas
G3/43 05473

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 NOVEMBER 1977

STANDARD TITLE PAGE

1. Report No. NASA TM-75064	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle ON THE DEVELOPMENT OF EARTH OBSERVATION SATELLITE SYSTEMS		5. Report Date November 1977
		6. Performing Organization Code
7. Author(s) Science and Technology Agency of Japan		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates Redwood City, California 94063		11. Contract or Grant No. NASw-2790
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration, Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Chikyu kansoku eisei shisutemu no kaihatsu ni tsuite," Science and Technology Agency of Japan, Tokyo, Japan, Report, July 12, 1977, pp 1-81

16. Abstract

Subsequent to the launching of the first LANDSAT by NASA, Japan has recognized the importance of data from earth observation satellites, has conducted studies, and is preparing to develop an independent system. The first ocean observation satellite will be launched in 1983, the second in 1985. The first land observation satellite is scheduled to be launched in 1987 and/by 1990 Japan intends to have both land and ocean observation systems in regular operation. The associated reception and data processing systems are being developed.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified-Unlimited

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 34	22. Price

FOREWORD

Since the United States launched the Earth Observation Satellite LANDSAT-1 in 1972, the pace of development in the area of earth observation from space has accelerated. Subsequently the U.S. has launched various kinds of earth observation satellites, and plans for earth observation satellites are being made in Europe, Canada, India and other countries. The installation of ground stations for direct reception from LANDSATs has proceeded very quickly in various countries of the world. This is especially noticeable in the developing nations. Research concerning analysis and utilization of satellite data is being carried out widely in various cooperating countries under the sponsorship of NASA, and attempts at partial utilization of the data are being made. In this background, Japan has recognized the need of developing its own independent earth observation satellites, and studies have been conducted for this purpose. It is urgently necessary that research and development based on the results of these studies be expedited.

ON THE DEVELOPMENT OF EARTH OBSERVATION SATELLITE SYSTEMS

TABLE OF CONTENTS

ON THE DEVELOPMENT OF EARTH OBSERVATION SATELLITE SYSTEMS

Science and Technology Agency, Tokyo, Japan

I. Outline of the Earth Observation Satellite System /2*

1. Characteristics of Remote Sensing from Satellites

Remote sensing from earth observation satellites has the following characteristics when compared with that from aircraft.

(1) A wide area can be observed for a short time (data can be obtained from an area of 185 x 185 km, when the satellite is at an altitude of 900 km. This is 3,000 times the area covered by an aircraft at an altitude of 3 km).

(2) The image information received is very accurate geometrically (remote sensing information is very difficult to correct when it is obtained by aircraft).

(3) Repeated observation over a wide area is easy (systematic data can be obtained for an organization which uses the system often).

2. Structure of the Earth Observation Satellite System /3

An earth observation satellite system is made up of earth observation satellites, ground receivers, a processing and storage system, a distribution system, and an analysis and utilization system. (See Figure 1.)

(1) The earth observation satellite
Earth observation information is collected by sensors and transmitted to ground reception and processing stations.

(2) Ground reception and processing stations
The information is received and geometrical corrections and annotations necessary for analysis are made.

(3) System for analysis and utilization
Information is extracted from the data (films, tapes, etc.) received from the reception and process system and presented for utilization.

---

* Numbers in the margin indicate pagination in the foreign text.

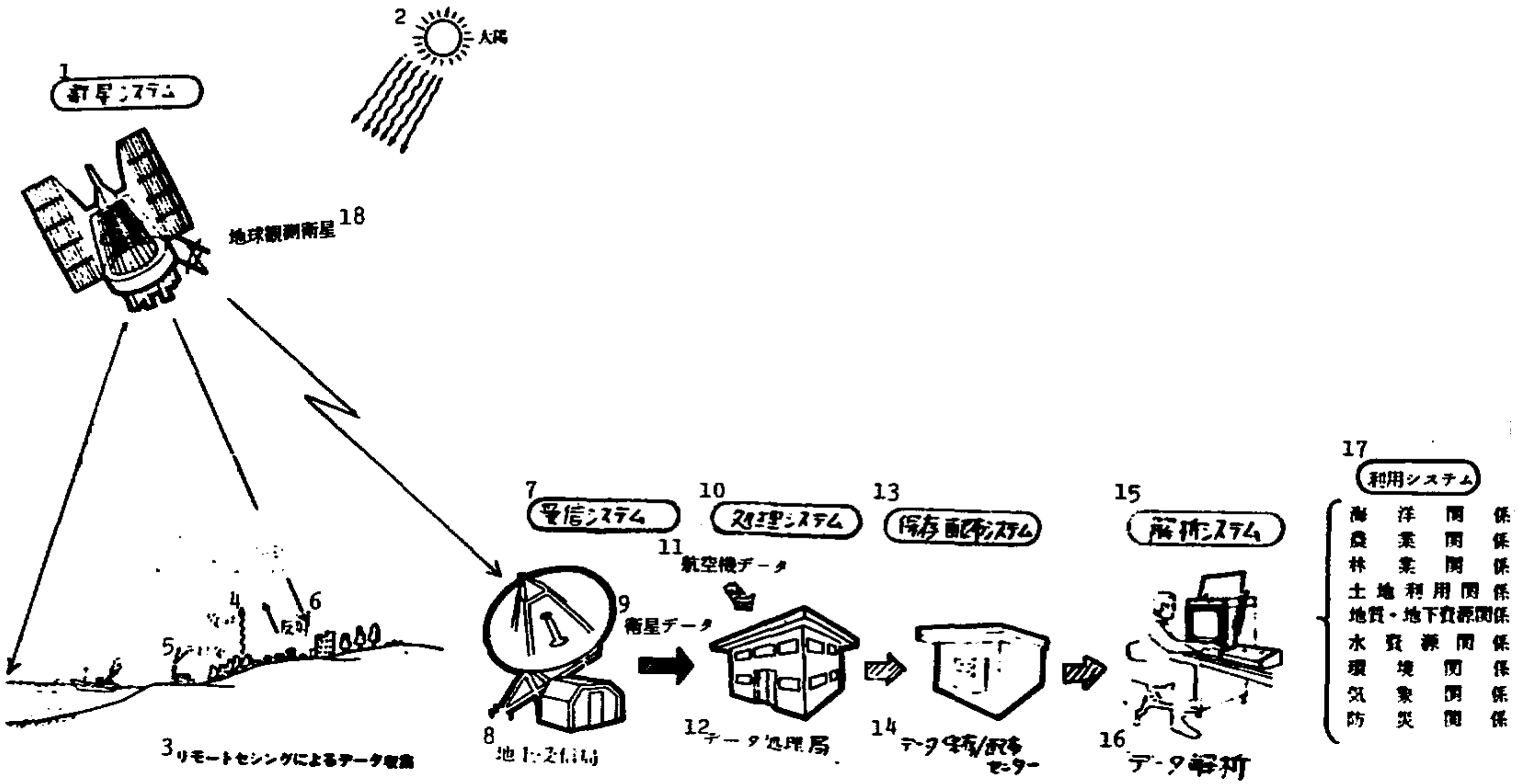


Fig. 1. Earth observation satellite system

Key: 1. Satellite system 2. Sun 3. Collection of data by remote sensing 4. Radiation 5. Targets 6. Reflection 8. Ground receiving station 9. Satellite data 10. Processing system 11. Data from aircraft 12. Data processing station 13. Storage and distribution system 14. Data storage and distribution center 15. Analysis system 16. Data analysis 17. Utilization system: Oceanic organizations, agricultural organizations, forestry organizations, land utilization organizations, geological and underground resources organizations, water resources organizations, environmental organizations, meteorological organizations and disaster-prevention organizations.

/5-6

3. Areas of Utilization of Earth Observation Satellite Data

Table 1 gives an outline of the areas of use of earth observation satellite data according to research done for several countries.

TABLE 1. OUTLINE OF THE AREAS OF UTILIZATION OF DATA FROM EARTH OBSERVATION SATELLITES /7

Area	Purpose for which used
Oceanic	For observation of water color, sea ice, salinity, waves, tsunami, high tides, surface water temperature, surface water salinity, oil slicks, substances suspended in the water, and the water depth in shallow seas.
Agriculture	Crop determination, estimates of production, classification of soil, irrigation planning, grazing control, investigation of water damage to agriculture, observation of damage by pests and disease.
Forestry	Investigation of forest resources, investigation of forest and forestation distribution, observation of forest fires, and observation of damage to forests by pests and disease
Land utilization	Preparation of classifications for land use
Geological, underground resources	Mineral prospecting, petroleum prospecting, investigations of volcanoes, investigations of earthquake zones, geothermal investigations, investigation of wind and water erosion, rock investigation, structural investigations and preparation of geological maps.
Water resources	Preparation of snow distribution maps, investigation of surface water distribution, investigation of water in soil, investigation of flooded areas and investigation of underground water.
Environment	Investigation of pollution in the atmosphere, investigation of ocean pollution, investigation of urbanization, and evaluation of wildlife areas.
Meterological	Investigation of smog dispersion, investigation of the effects of industry on the weather, investigation of gravity in the lower atmosphere, research in atmospheric radiation and investigation of tornados.

(TABLE 1 continued)

(Area)	(Purpose for which used)
Disaster prevention	Preparation of flood danger maps, investigation of the amount of water in dam basins, observation of the change of ice in rivers, preparation of earthquake warning maps, investigation of droughts, observation of grass and forest fires.

II. Trends in Various Countries Concerning Earth Observation Satellites /9

1. Trends Concerning Earth Observation Satellites

In the 1970's the United States has launched with great success the resources investigation satellites LANDSAT-1 and 2 for the purpose of gathering information concerning land areas and the weather satellites NOAA-3, 4 for the purpose of weather observation. The United States plans to continue through the 1980's, launching LANDSAT-C, LANDSAT-T-D and SEOS for the purpose of collecting information concerning land areas. In addition, the U.S. intends to launch the SEASAT series for the purpose of collecting information concerning ocean areas.

In countries outside the U.S., work on the development of earth observation satellites is proceeding at a fast pace.

Tables 2 and 3 give an outline of the essentials concerning the earth observation satellites of the various countries and the launching schedules.

2. Trends Concerning Ground Communications

Along with plans for earth observation satellites, the installation of ground stations for direct reception and processing of data from the satellites is proceeding rapidly in many countries. Information concerning the installation of these stations is given in Tables 2 and 4. /10

Also, in the Science and Technology sub-committee of the United Nations Committee for the Use of Outer Space for Peaceful Purposes, exploratory studies are being made for the establishment of international local and control centers for the reception of remote sensing data. According to these studies, it will be necessary to establish data reception centers in 14 countries, including Japan.

TABLE 2. OUTLINE CONCERNING EARTH OBSERVATION SATELLITES OF VARIOUS COUNTRIES

Name of country	Name of satellite	Launching time (scheduled)	Designed life	Mission and mission equipment (abbreviated)	Orbit factors	Communications frequencies (MHz)			Data rate (Kbit/s)		Notes
						Use	Reception	Transmission	Real time	Play back	
The United States	LANDSAT-C	Early 1978	2	Mission ..... collection of earth surface image data. Mission equipment: a- Two 1-band return beam vidicon cameras b- A 5-band multispectrum scanner c- A data collection system d- A wide-band video tape recorder	a-Solar synchronous quasi-recurrent orbit b-Altitude of orbit 915 km c-Angle of orbit inclination 99° d-Rotation period 133 minutes e- Recurrent period: 18 days	a-Tracking b-Command c-MSS or RBV data d-RBV or MSS data e-DCS data f-Tracking g-Command	2,106.4 2,106.4 -- -- 401.55 -- 154.2	2,287.5 -- 2,265.5 2,229.5 -- 137.86 --	1 or 5 15,000 -- -- -- -- 	24 -- 15,000 -- -- -- --	Launching schedule has been confirmed by Congress 960 kg
	SEASAT-A SEASAT-B	1982 May 1978	3 3	Mission ..... collection of oceanic data. Mission equipment: a- Radar altimeter (ALT) b- Synthetic aperture radar (SAR) c- Scatter meter (SCAT) d- Scanning multichannel microwave radio-meter (SMMR) e- Scanning radiometer	a-Solar nonsynchronous quasi-recurrent orbit b-Orbit height 800 km c-Angle of orbit inclination 108° d-Rotation period 101 minutes	a-Observation data b-Observation data c-Command d-Tracking	 2,106.4 2,106.4	2,287.5 2,265.5 -- 2,287.5	25 15,060 1 --	640 -- -- --	Launch sched. confd. by Cong. Wt. of sat. 1,814 kg.
	LANDSAT-D	1981	2	Mission ..... collection of data concerning earth's surface. Mission equipment: a- A 7-band thematic mapper (TM) b- A 5-band multi-spectrum scanner c- A data collection system (DCS)	a-Solar synchronous quasi-recurrent orbit b-Orbit altitude 705 km c-Angle of orbit inclination 99° d-Period of rotation: 100 min. e-Recurrent period 17 days	a-Command b-Tracking and observation data c-Observation data d-Observation data	2,106.4 2,106.4	 2,287.5 8,180 8,360 15 GHz	-- 20/200 240,000 20,000 240,000	-- 400 -- -- --	Launch plan not yet approved by Congress.

/11-14

(Table 2 continued)

Name of country	Name of satellite	Launching time (scheduled)	Designed life	Mission and mission equipment (abbreviated)	Orbit factors	Communications frequencies (MHz) Use	Reception	Transmission	Data rate (Kbit/s) Real time	Play back	Notes
The United States	SEOS	1982	5	Mission ..... regular observation of the earth's surface data collection. Equipment: a- Large earth survey telescope (LEST) b- Microwave sounder c- Infrared sounder d- Data collection system	a-Earth synchronous orbit b-Orbit altitude 35,800 km c-Angle of orbit inclination 2° d-Position 100 West longitude	a-Tracking b-Observation data c-Observation data d-Observation data e-Command	2,051156 -- -- -- 2,051156	8,1675 8,1675 8,0825 2,2175 --	-- 10 50,000 2,000 --	-- -- -- -- --	Launch plan not yet appvd. by Congress
	NIMBUS-G	Oct. 1978	1	Mission ..... observation of atmospheric pollution over a wide area. Mission equipment: a- CZCS b- ERB c- LIMS d- SAMS e- SAM II f- MAPS g- SBUV/TOMS h-SMMR i- T 11 R j- Tape recorder k- Data collection system	a- Solar synchronous quasi-recurrent b- Orbit altitude 917 km c- Orbit inclination angle 99°	a-Observation data b-Observation data c-Observation data d-Command e-Tracking	 209351 209351	1,702.5 2,2110 2,2735	800/4 " "	800	Weight of satellite 960 kg
	HCMM	Feb. 1978	1	Mission ..... measure thermal income and expenditure on the surface of the earth. Mission equipment: Heat Contents Mapping Radiometer (HCMR)	a-Solar synchronous b-Orbit altitude 600 km c-Recurrent period 1.5-3.5 days	a- Observation dats b- Observation data/ tracking c- Command	-- -- 149,52	2,246.0 136.17 --	2.5 1.25/ 2.5/5.0	undecided	Weight of satellite 130 kg

/17-18/

(Table 2 continued)

Name of country	Name of satellite	Mission	Program progress	Orbit factors	Sensors on board	Presence or lack of data collection system	Presence or lack of tape recorder	Launch time (scheduled)
European Space Agency (ESA)	SPOT	Similar to that of LANDSAT. By a command from earth, a specific band can be selected from 9 bands of video sensor data for transmission.	Feasibility studies are being conducted	a- Orbit altitude 800 km b- Orbit inclination angle 98° c- Period of recurrence 10 days	a- Multispectrum scanner (MSS) b- Wave length: - 0.49-0.90 μm (bands 1-9) - 3-5 μm (band 10) - 10-12 μm (band 11) c- scanner width: 300 km d- Image-resolving power: 100 m (visible), 200 m (infrared). In addition the development of a sensor with a resolving power of 20 m is being planned.	Present	Undetermined	About 1983
	PAMIRASAT (Passive Microwave Radiometer Satellite)	Observe all marine meteorological phenomena and monitor the soil, water, sea ice, and water pollution	A feasibility study was done in 1974	Undetermined	Passive Microwave Radiometer Frequencies: 3.7, 19, and 31.8 GHz	Undetermined	Undetermined	In the middle 1980's

(Table 2 continued)

Name of country	Name of satellite	Mission	Program progress	Orbit factors	Sensors on board	Presence or lack of data collection system	Presence or lack of tape recorder	Launch time (scheduled)
ESA	SARSAT (Synthetic Aperture Radar Satellite	All-weather observation of European topography	The first feasibility study has been completed and the next program is under discussion	a- Orbit altitude 567 km b- Orbit inclination angle 98° c- Period of recurrence: 17 days	a- Synthetic aperture radar (SAR) b- Frequency: 10 GHz (X band) c- Scanning width: 80 km d- Image-resolving power: 25 m	Undetermined	Undetermined	Middle 1980's
Canada	Undetermined	Demonstration of operational sea ice monitoring	A feasibility study was done in 1974	a- Altitude 1,000 km b- Orbit inclination angle 99° c- Period of recurrence: 1-4 days	a- Microwave radar (SAR) b- Frequency: L band c- Scanning range 400 km d- Image-resolving power: 100 m	Undetermined	No tape recorder	1983-1985
Soviet Union	Undetermined	Similar to LANDSAT	Satellite believed to be under development	a- Orbit altitude 500 km b- Orbit inclination angle 97°	a- Vidicon camera (VC) b- Film camera (FC) c- Frequency bands: 0.45-0.9 μm band for (VC), 7 bands between (0.5-1.2) μm for (FC) d- Scanning range 200-300 km e- Image-resolving power: 100 m (VC), 80-120 m (FC) f- The satellite system includes on-board film developing equipment and an electronic scanner.	Undetermined	Has tape recorder	1977-1978

/19-20

/21-22

(Table 2 continued)

Name of country	Name of satellite	Mission	Program progress	Orbit factors	Sensors on board	Presence or lack of data collection system	Presence or lack of tape recorder	Launch time (scheduled)
India	SEO (Satellite for Earth Observation)	a- Earth observation experiments b- Collection of information concerning use of water from rainfall and information concerning the oceans c- This satellite is to be the basis for future observational satellites	Agreement concluded with Soviet Union concerning preparation of launching plans. 2 EMs scheduled for completion in 1977	Orbit altitude 525 km Orbit inclination angle 51°	a- 2 TV cameras (vidicon) b- Frequency bands: 0.54-0.66 m, 0.75-0.35 m (340 km^2 x 340 km^2 resolving power 1 km) c- 2 microwave radiometers (2 frequencies) (SAMIR)	Unclear	Unclear	1977-1978

TABLE 3. LAUNCHING PLANS OF VARIOUS COUNTRIES FOR EARTH OBSERVATION SATELLITES

year of launching / name of country	[illegible]	[illegible]	1978	1979	1980	1981	1982	1983	1984	1985
Japan		(GMS) △ VISSR				(GMS-II) △ (ETS-II) △		1* MOS-1 △		2* MOS-2 △
The United States	No. 1, No. 2 △ MSS RBV; LAGEOS △ geodetic satellite		No. 3 △ MSS RBV LANDSAT series; NIMBUS-G △ pollution monitoring CZCS; HCMM △ temperature measuring HCMR; SEASAT-A △ (sea mapping) (sea conditions)	GEOPAUSE △ GRAVSAT △ Gravity	MAGSAT △ Magnetic force	No. 4 △ TM	SEOS △ stationary; SEASAT-B △			
				Changes in the crust of the earth			plans for experimental physiological observation of oceans (EOPAP)			
ESA								SPOT △ visible thermal infrared; visible near infrared	microwave	radiometer; synthetic aperture radar
Canada								sea △ observation		aperture radar

In addition, India, West Germany, and the Soviet Union are discussing development.

Scheduled to carry SAMSAT sensor (microwave altimeter, microwave radiometer, synthetic aperture radar, visible infrared radiometer)

[1] MOS-1 (oceanic): visible near infrared radiometer (4 band 500m), microwave radiometer (2 band: 25 km).

[2] MOS-2 (oceanic): microwave radiometer, microwave altimeter, microwave scatter meter

/23-24

/25-26

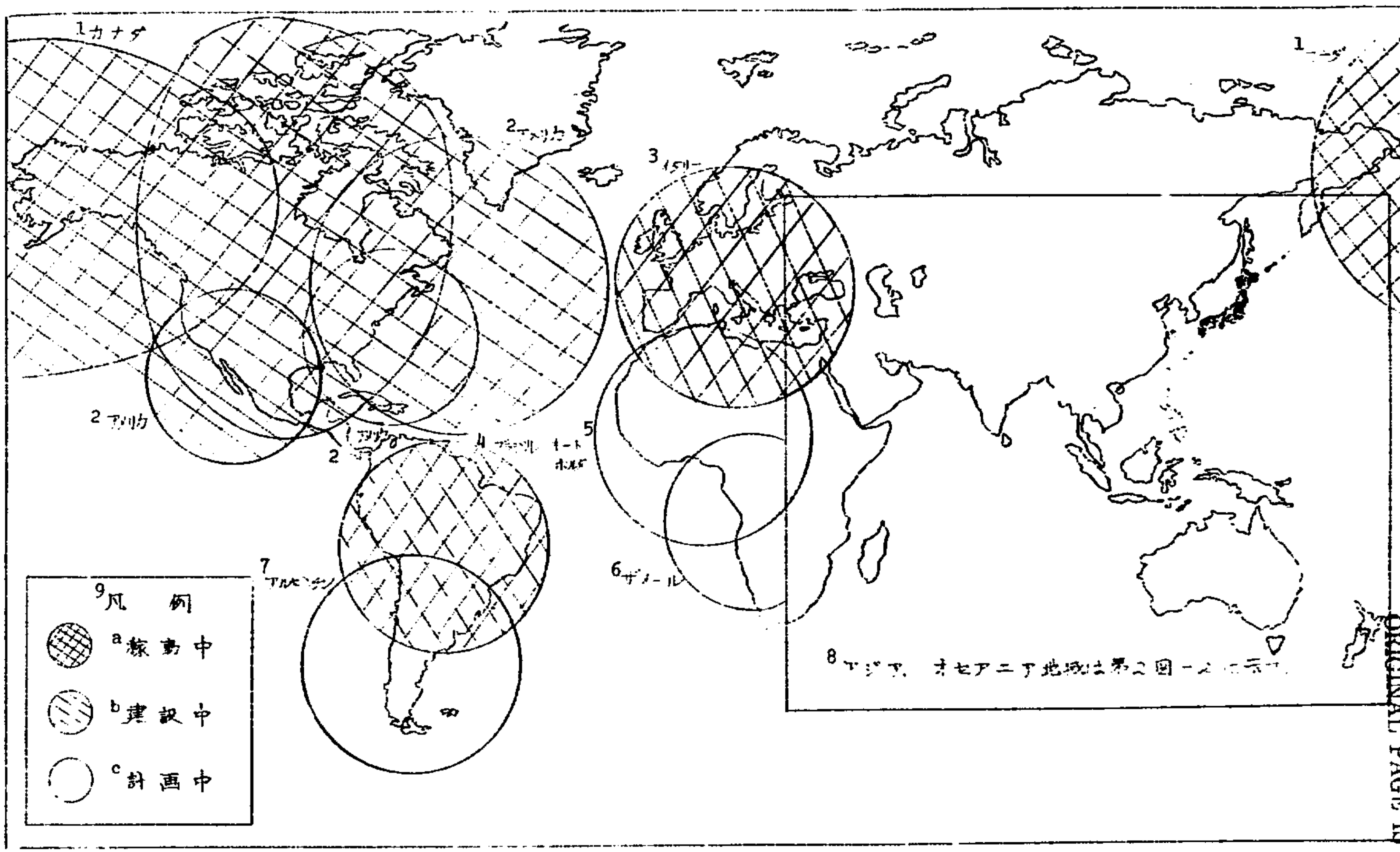


Fig. 2. Status of installation of ground stations in each country

Key: 1. Canada 2. America 3. Italy 4. Brazil 5. Upper Volta 6. Zaire
7. Argentina 8. The areas for Asia and Oceania are shown in Figure 2.2.
9. Symbols: a) In operation b) Under construction c) Planned

/27-28

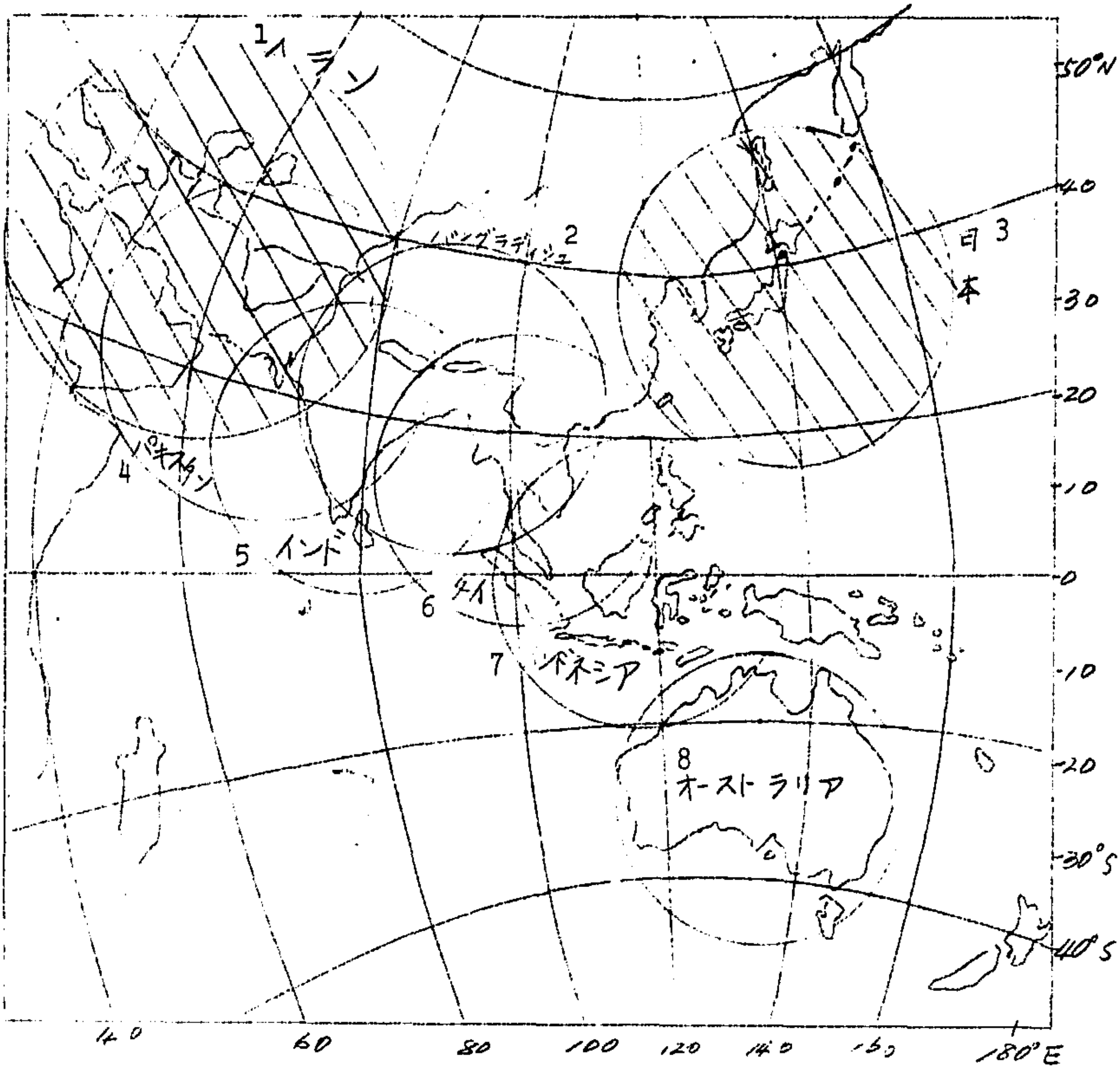


Fig. 2.2. Installation plans for ground stations for Asia and Oceania areas

Key:

1. Iran
2. Bangladesh
3. Japan
4. Pakistan
5. India
6. Thailand
7. Indonesia
8. Australia

TABLE 4. STATUS OF INSTALLATION OF GROUND STATIONS FOR LANDSAT

Status	Country's name \ Year	1972 (47)	1973 (48)	1974 (49)	1975 (50)	1976 (51)	1977 (52)	1978 (53)	1979 (54)	Notes
	Planned launches of LANDSATs	LANDSAT-1 △			LANDSAT-2 △			LANDSAT-C △		LANDSAT-D planned for 1981
In process of installation	Japan								▲	
In operation	America	▲ #1 ▲ #2 ▲ #3								
	Canada	▲ #1				▲ #2				
	Brazil			▲						
	Italy					▲				
In process of installation	Iran							▲		

Countries with installation plans: Indonesia, Pakistan, Thailand, Zaire, Upper Volta, Bangladesh, Argentina, Chile, Australia and India

/29-30

III. Particulars on the Status of Research and Investigation in Japan in Connection with Earth Observation Satellites /31

1. Participation in Research and Analysis of Data from American Earth Observation Satellites

After the United States launched an earth observation satellite in 1970, all countries of the world were invited to participate in analytical research on data obtained from satellites. In accordance with this invitation, in Japan in December of 1970, an "Investigative Council concerning the Technical Interpretation of Resource Satellite Data" was established in the Research Coordination Bureau of the Science and Technology Agency with specialists from government organs and universities as members. Research themes were selected by this council, and research carried out (see Table 5).

In participating in this research, it gradually became clear that earth observation satellite data was useful to Japan.

2. Development of Technology for the Utilization of Remote Sensing Information

The things most necessary for analyzing LANDSAT data are photograph interpretation technology using optical equipment, digital information interpretation technology suitable for quantitative analyses, and ground collation with aircraft and land sur- /32 veys in order to recognize what is expressed by the satellite data. Recognizing this, the Science and Technology Agency conducted "composite research for the development of technology for the utilization of remote sensing information" during a 3-year period from 1973 using funds for special research. Subsequent to this, from 1976, there is a 3-year plan in effect for carrying out "composite research on methods of collecting remote sensing information, on processing data, and on methods of interpretation," which is research concerned with the development of data correction technology. Then, from 1977, a 5-year plan of research and development will be continued on "Oceanic remote sensing technology," which will be concerned with the optical characteristics of sea ice.

In addition, government organs and civil organizations have recognized the usefulness of remote sensing information and analytic research in proceeding from the point of view of agriculture, land use, underground resources, geological topography, atmospheric resources, weather, observation of the environment and other fields.

TABLE 5. PARTICIPATION IN THE ANALYTIC RESEARCH OF AMERICAN EARTH OBSERVATION SATELLITE DATA

Satellite	Research plan	Japan's research theme
LANDSAT-1	ERTS-1 (1972-74)	1- Investigation of Japan's environmental patterns 2- Research concerning medium-scale atmospheric phenomena, winter monsoon clouds, and snowfall
Sky lab	EREP plan (1972-74)	1- Investigation of changes in Japan's environmental patterns 2- Research concerning medium scale atmospheric phenomena, winter monsoon clouds and snowfall 3- Effect of ice in the Okhotsk Sea on the Oyashio Current
LANDSAT-2	ERTS - follow-up plan (1975-)	Investigation of changes in Japan's environmental patterns 1) Research on soil erosion caused by the melting of soil water in Hokkaido in late spring 2) Establishment of ecological indicators of change in environmental conditions by observing local vegatation cover and its condition of growth 3) Putting into practical use space data for confirming environmental changes in coasts and off-shore areas /37 a- Preparation of topographical maps showing features of coastal areas changed by sedimentation and erosion b- Determination of coastlines c- Investigation of the process of transformation in the oceans caused by interfering actions of man in the natural environment d- Observation of the flow patterns of rivers and polluted water entering the sea, and research on the process of dispersion of coastal pollution e- Research concerning changes in the Kuroshio current f- Research on the occurrence of red tides and damage caused by them

3. Surveys done by the Science and Technology Agency Concerning Earth Observation Satellite Systems /33

1) The Research Coordination Bureau of the Science and Technology Agency (below called the Science and Technology Agency) recognized that the establishment of a data reception and processing technology using American satellites prior to the development of satellites was necessary for the development of an efficient earth observation satellite system for Japan and the necessity of first installing ground reception and processing stations. On the basis of this, in 1974 a case study concerning reception and processing was conducted for the purpose of developing and installing reception and processing stations in Japan. The theme of the research was "a study concerning a system for the reception and processing of remote sensing information from earth observation satellites."

2) Subsequently, surveys were carried out concerning (1) earth observation satellite development in foreign countries and (2) areas in which earth observation satellite data could be used in Japan. The theme of these surveys was "studies concerning earth observation satellites." Using the results of these surveys as a basis, a case study was conducted concerning (3) earth observation /34
satellites for Japan.

3) Also, in 1976, detailed studies and discussions were held on ways of expediting development and on the missions of Japan's earth observation satellites for the next 15 years. At the same time, investigative research was done concerning the necessary sensing equipment to be carried on the satellites, methods of "berthing," and development prospects. The mission, equipment to be carried, and the development schedule for the first earth observation satellite were clearly decided upon at that time.

The mission requirements of earth observation satellites from the standpoint of areas of utilization in Japan, which were surveyed during this investigative research, are shown in Table 6.

4. Investigative Research Done by Space Development Project Groups

1) In 1975, based on the results of the surveys conducted by the Science and Technology Agency, investigative research was done concerning earth observation satellite systems and satellite trends, togather with investigative surveys concerning ground station design, the necessary "software" for ground station operation, and the sensing equipment carried on satellites. These studies were done under the theme "investigative research concerning earth observation satellite systems."

2) In 1976, under the theme, "design research in connection with earth observation satellite ground reception systems," design

/39-40

TABLE 6. EARTH OBSERVATION SATELLITE MISSION REQUIREMENTS FROM THE STANDPOINT OF AREAS OF USE IN JAPAN

Area	Utilization	Object of observation	Ground resolution power or accuracy	Observation period	Observation width	Observation area	Sensor	Necessary frequency bands	Notes
Oceanic	Investigation of oceanic physiological phenomena, state of sea surface, water color and temperature of sea surface, distribution of sea ice (topography of sea bottom for shallow seas)	The ocean	100 m - 1km	1-1/7 days	300 km	The sea near Japan	MSS SAR ALT	0.45-1.1 μm 10.4-12.6 μm 1.3-CHz	Possible application to construction at sea
	Application to fisheries and oceanography: surface water temperature, sea currents, sea color	The ocean	10-50 m (Temperature accuracy ±0.1-0.5°C)	2/ days (1.75-15 days)	90-180 km (10-50 km)	Sea near Japan and off-shore	MSS VIIR camera	0.44-0.86 μm 10.5-12.5 μm	→ 0.44-0.54 μm 0.54-0.62 μm 0.62-0.69 μm 0.70-0.86 μm Possible application to the study of sea pollution by estimating the degree of suspended matter & amount of plankton from the sea color
	Investigation of the environment of lakes and lagoons: surface water temperature, sea color	Lakes and lagoons	50-100 m	1/10-20 days	100 km	Large lakes & lagoons	MSS	0.5-1.1 μm 10.5-12.5 μm	Altitude about 400 km
Disaster prevention	Investigation of coastline erosion	Sea coast	50 m-1 km	1/ year	100-200 km	The entire country	SAR T M	1.3 CHz 0.5-1.1 μm	
	Investigation of damage from flood waters and high tides, etc. (flood inundation maps and maps showing state of damage)	Flat lands, seacoasts	50 m -1 km	At all times	100-200 km	The entire country	MSS SAR	0.45-1.1 μm 1.3 CHz	

(Table 6 continued)

Area	Utilization	Object of observation	Ground resolution power or accuracy	Observation period	Observation width	Observation area	Sensor	Necessary frequency bands	Notes
"	Landslides, avalanches, rock falls (mapping of avalanche mountains)	Mountain areas: amount of soil water, land slope, vegetation	10-20 m 50-100 m	All season, all times 1/10-20 days	100-200 km	The entire country	MSS SAR MBS	0.45-1.1 μm 1.3 CHz	Altitude 400 km
	Investigation of disease and pest outbreaks in agriculture	Flatlands, mountains: diseased crops	50 m-1km less than 1m	1/1-3 months 1/day	100-200 km 50 km	The entire country	MSS	0.45-1.1 μm	
Environment	Investigation of environmental changes in cities: environmental classification maps, environmental pollution maps	Cities	30-80 m	1/1-3 months	100-200 km	Major cities	MSS	0.45-1.1 μm	
	Investigation of atmospheric pollution	Cities: polluting substance: aerosol	50 m -1 km 50-100 m	1/day 3/days	200 km 100 km	Major cities	RBV MSS SMMR Laser radar	0.45-1.1 μm	Concrete examples of objects of observation: NOx, NO.NC₂, THC.Ox, Dust
	Investigation of pollution in sea areas	Sea areas around cities, flat lands, water temperature and color, ocean pollution	50-500 m ±0.5°C 50-100 m ±50 m	1/day-month 1/10-20 days 4/days	100-200 km 100 km "	Entire country	MSS SAR VIIR SMMR	0.45-1.1 μm 1.3 CHz 10-1.1 μm 11-12.5 μm c- An altitude as low as possible	a- It is believed possible to determine the kind and density of organisms in large red tides from the color of the water (sea) b- The relationship between water color and transparency can be determined

/40-41

/42-43

(Table 6 continued)

Area	Utilization	Object of observation	Ground resolution power or accuracy	Observation period	Observation width	Observation area	Sensor	Necessary frequency bands	Notes
"	Other: follow-up monitoring for evaluation of the effects on the environment	All of the items listed above a- sea areas b- heat distribution for all areas c- changes in land cover	50 m 20-50 m 10 m	1/day 2/days 1/15-30 days	100-200 km 100 km 100 km	Major developed areas and their surroundings	MSS Long-focus camera	Under investigation	
	Analysis of the thermal environment of cities	Cities	10 m	2/days	200 km	Major cities			Measurement of the vertical temperature distribution from a stationary satellite before sunrise and at 1400
Condition of land	Investigation of conditions of land use	Flat fields, mountain land	50-100 m	1/year	200 km	The entire country	MSS camera VIIR	0.45-1.75 µm color, infrared 0.4-0.7 µm	Preparation of land use classifications using satellites (combined with data from aircraft)
	Investigate state of land use (high density areas)	Cities	30-80 m (10-30 m)	1/3-6 months	100-200 km	Environs of major cities	MSS	0.45-1.1 µm 10.2-12.5 µm	
	Investigate vegetation (grass lands, hemp, mixed forest and grass land)	Mountains, flatlands	25-100 m	1/3 months	100-200 km	Entire country	MSS SAR camera	0.45-1.75 µm 1.3 CHz Color, infrared	

(Table 6 continued)

Area	Utilization	Object of observation	Ground resolution power or accuracy	Observation period	Observation width	Observation area	Sensor	Necessary frequency bands	Notes
"	Soil classification maps	Soil type classification	30-100 m	1/3 months	100-200 km	Hokkaido, Tohoku district (entire country)		0.45-1.75 μm 1.3 GHz	a- Determination by amount of moisture in soil b- Determination of soil by amount of local decomposed vegetation in the soil
	Investigation of changes in forest conditions	Contents of forests	30-100 m (10-15 m)	1/3 months	100-200 km	Entire country	MSS SAR 3*	0.45-1.75 μm 1.3 GHz Infrared color	Altitude 400 km
	Investigation of trends in rice-producing districts	Flatlands	20-100 m	1/3 months	100-200 km	Hokkaido, Tohoku district (entire country)	MSS SAR	0.45-1.75 μm 1.3 CHz	
	Other: investigate area under cultivation, investigate geological structures	a- Rural areas b- Faults-rocks	0.5-1 m 30-50 m	1/week 1/3 months	100 km 10-50 km	Entire country	MSS-SAR SMMR SAR	Under investigation	Estimation of crop yields
Hydrology	a- Water resource reports b- Surface water distribution c- Snow cover d- Sand accumulation	a- Mountain areas b- Flatlands	50-100 m	1/1-30 days	200 km	Entire country	DCS MSS SAR	0.45-1.1 μm 1.3 GHz	
	Rivers a- Water area b- Vegetation c- Geological features d- Topography	a- Mountain areas b- Flatlands	50-100 m (10-15 m)	1/day 1/1-2 days	200 km (100 km)	Entire country	DCS MSS SAR	0.45-1.75 μm (0.4-1.3 μm)	To be aware of hydrological changes in rivers

[3] High image-resolving power, long-focus camera

/43-46

(Table 6 continued)

Area	Utilization	Object of observation	Ground resolution power or accuracy	Observation period	Observation width	Observation area	Sensor	Necessary frequency bands	Notes
Meteorology	Investigation of medium-scale atmospheric phenomena a- cloud distribution b- atmospheric temperature distribution c- land surface temperature, cloud temperature	Clouds	500m-10m 1-10 km 0.5-10 km	1/day- 3 months	300 km	Entire country	VIIR MSS	{0.49-0.94 m 10.5-12.5 m {0.45-1.1 m 10.4-12.6 m	±1°C
	Data for evaluating the income and expenditure or radiation	Short-wave radiation from the surface, upward infrared radiation	Under discussion	3/day time period 2/night	10 km All land surface within visual field	The proximity of Japan	(MSS) Spectro-radiometer	a- Ultraviolet, visible b- Near infrared, infrared 130	a- Since there is an absolute value for the amount of radiation radiated into the atmosphere, calibration is essential b- Analysis by combining with values measured on the ground

/45-46

research was conducted concerning ground reception and recording installations together with research on the "software" necessary for the operation of these installations.

IV. Outline of Plans for the Development of Earth Observation Satellites in Japan /47

1. Basic Point of View Concerning the Development of Earth Observation Satellites

Observation of the earth from outer space as a way of making highly accurate and repeated observations over wide areas is not only a means of monitoring sea, land and ecological phenomena, but also plays an exceedingly important role in providing a means of predicting the occurrence of phenomena, thus enabling us to establish measures to cope with them.

Taking into account the above role for earth observation satellites, their usefulness in many fields, and the prospects for the associated technology, the development of earth observation satellites in Japan is appropriate, based on the following conceptions.

1) Earth observation satellites should be developed not only to meet domestic requirements for the next 15 years, but should be developed with the long-term objective of establishing a technology that can develop independently, while promoting international cooperation.

2) Since the orbits and sensors of satellites differ greatly, according to the object of observation, two systems should be developed: satellites for the collection of chiefly oceanic data (marine observation satellites), and satellites for the collection of chiefly land data (land observation satellites). /48

3) In considering the importance, urgency, and technical feasability of land observation satellites and ocean observation satellites, it was decided to postpone the launching of a land observation satellite, and to launch the first ocean observation satellite in 1983. The second satellite is scheduled to be launched in 1985, and basic satellite technology will be established in the late 1980's. In regard to land observation satellites, basic technology will be established by 1980.

4) As development progresses, the systematic growth of associated technology will be achieved to the best of our ability as Japan's independent technology.

2. Outline of Development Plans

2.1. Ocean observation satellite

1. Necessity for development. Heretofore, the observation of /49 the oceans has been limited to spot or linear observation by survey ships, and there was no effective means of constant observation over a wide area. With artificial satellites, it is possible to conduct continuous observations of the surface of the sea, and the rapid development of oceanographical research concerning ocean surveillance, the use of sea resources, and ocean physiology is expected.

The recent 200 nautical mile fisheries waters question has strongly confirmed the necessity of investigative observation of the seas and the necessity of effectively and rationally using marine resources. It is strongly desirable that a satellite for the observation of ocean currents, waves, and temperature distribution of sea water be launched at an early date.

The United States plans to launch a SEASAT in 1978, but it is essential that Japan develop at an early date a system of observation which has the range of observation, period of observation, and accuracy that meets the needs of Japan.

2. Long-range concepts. First, in order to develop an earth observation satellite system suitable for Japan, satellite data reception and processing technology will be acquired by the operation of ground reception and processing installations which will /50 be completed in 1978. Experiments will be conducted to obtain the basic technology necessary for an earth observation satellite with a triaxial attitude-control data transmission system with the experimental technical satellite (ETS III), which will be launched in 1981.

Putting the results of the above experiment into practice, Japan's ocean observation satellite will be developed. The schedule below is believed to be suitable.

i) The first ocean observation satellite (MOS-1)
- a) Purpose: to establish technology common to observation satellites
- b) Mission: observation of oceanic phenomena, concentrating on the color of the sea surface and temperature
- c) Sensors: visible radiometer
infrared radiometer
microwave radiometer
- d) Target year for launching: 1983 /51

ii) The second ocean observation satellite (MOS-2)
- a) Purpose: to establish the basic technology for ocean observation satellites

b) Mission: observe the oceanic phenomena of waves and surface winds

c) Sensors: microwave radiometer
microwave altimeter
microwave scatter meter

c) Target year for launching: 1985

iii) Third ocean observation satellite (MOS-III)

a) Purpose: utilization as an ocean observation satellite

b) Mission: observation of ocean phenomena such as ocean currents, waves, temperature distribution of sea water, etc.

c) Sensors: visible infrared radiometer
microwave radiometer /52
microwave altimeter
microwave scatter meter
image radar

d) Target year for launching: 1989

3. Present research and development plans.

i) Conduct the research and development of the mission equipment and complete preliminary plans for the systems for the first ocean observation satellite in 1978, based on the research results up to 1977

ii) Plan the system concepts for the second ocean observation satellite in 1978

2.2. Land observation satellite

1. Necessity for development. The problems accompanying the increase of population and the concentration of population into cities, the expansion of industrialization, and the deterioration of the environment are becoming increasingly real in Japan and throughout the world. /53

To cope with these problems, the following list of systems must be established as soon as possible. Observation by satellite is an indispensable part of the following systems, and will become increasingly important.

i) A system for the management of agriculture and forest resources and the management of water resources is necessary so that measures can be taken to ensure a timely supply. For this, predictions of harvests and water run-off must be made from a constant knowledge of agriculture production and forest growth, and from the amount of snow accumulation.

ii) The prewarning signals of widespread and irregularly-occurring natural disasters must be accurately recognized and reported for forewarning and disaster prevention. There must be a disaster reporting system which will, by rapid reporting of post-disaster conditions, insure that necessary relief measures can be taken.

iii) By regularly monitoring the rapid changes in land utilization and taking the necessary measures early, it is possible to establish a land-use and environment- /54 monitoring system conducive to the use of land in the most desirable way.

To establish the above systems for Japan as well as for other countries, the development of, and installation of, an independent land observation satellite system is necessary as a link in local and international cooperation. It is expected also that land observation satellites will be an effective means for understanding geological structures, geothermal distribution, sea pollution conditions, etc.

2. Long-term concepts.

1) Since LANDSAT reception is available now, the acquisition of the necessary analytic technology is planned by making use of this. The establishment of technology common to earth observation satellites is planned from the experience of the first ocean observation satellite (MOS-1). Then, this technology will be combined, and research and development work done for the realization of high resolving power sensors, and information processing.

2) Based on the results of the above, a practical sea observation satellite will be put into operation and from this stage, the development and launching of land observation satellites will take place according to the following schedule. /55

i) The first land observation satellite (LOS-1)
   a) Purpose: to establish basic technology for land observation satellites
   b) Mission: the observation of vegetation, snow accumulation, conditions of land use, disaster conditions, water pollution, warm exhaust water, etc.
   c) Sensors: a high resolving power sensor (30 m), visible-infrared radiometer
   d) Orbit: solor synchronous orbit
   e) Target year for launching: 1987

ii) The second land observation satellite (LOS-2)
   a) Purpose: utilization as a land observation satellite
   b) Mission: the accurate observation of vegetation, prewarning signals for disasters, conditions of land use, etc., and surveillance of water and atmospheric /56 pollution

/57-58

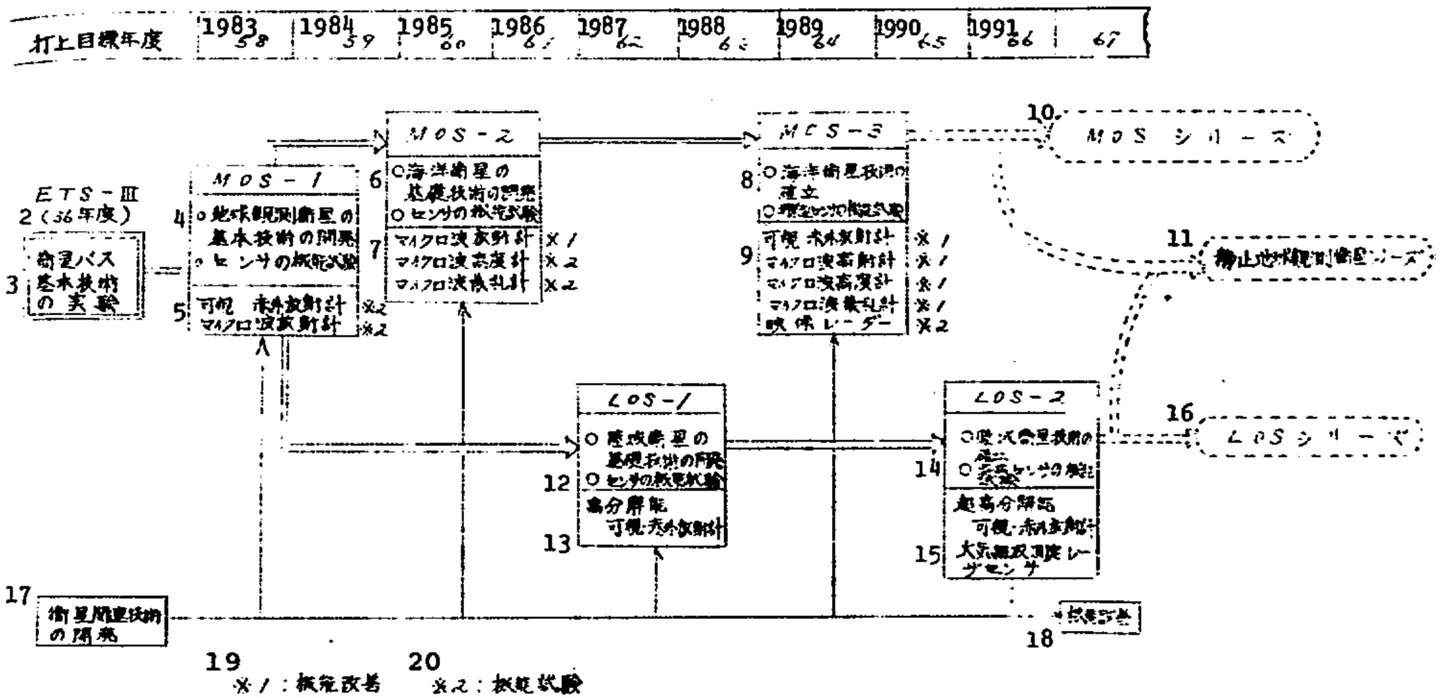
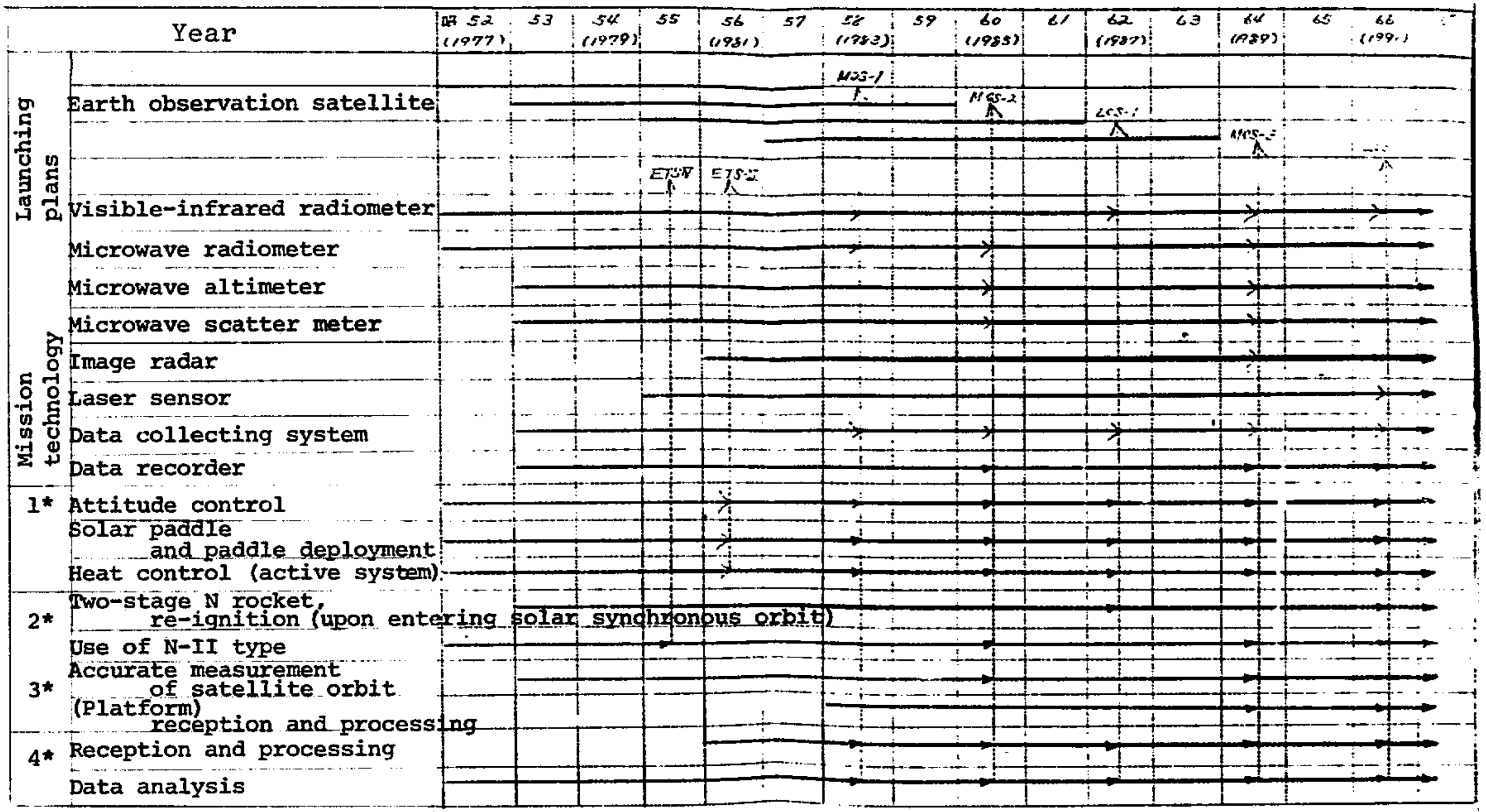


Fig. 3. Launching schedule for land observation satellites

Key: 1. Target year for launching 2. 1981 3. Experiments in the basic technology of satellite berthing. 4. The development of basic technology concerning earth satellites and sensor performance tests 5. Visible-infrared radiometer, microwave radiometer 6. The development of basic technology for ocean observation satellites, sensor performance tests. 7. Microwave radiometer, microwave altimeter, microwave scatter meter 8. Establishment of ocean satellite technology, performance tests of future sensors 9. Visible-infrared radiometer, microwave radiometer, microwave altimeter, microwave scatter meter, image radar 10. MOS series 11. Stationary earth observation satellite series 12. Development of basic technology for land observation satellites 13. High-resolving power, visible-infrared radiometer 14. Establishment of land observation satellite technology, performance tests of future sensors 15. Ultrahigh resolving power, visible-infrared radiometer, laser sensor for measuring the constituents of the atmosphere 16. LOS series 17. Development of satellite-associated technology 18. Performance improvement 19. Performance improvement 20. Performance tests

/59-60

TABLE 7. LONG-TERM DEVELOPMENT SCHEDULE FOR BASIC EARTH OBSERVATION SATELLITE-ASSOCIATED TECHNOLOGY



[1]Satallite technology
[2]Launching technology
[3]Tracking technology and reception
[4]Processing technology and interpreting technology

c) Sensors: ultrahigh resolving power (10 m), visible-infrared radiometer and a laser sensor for measuring the components of the atmosphere
d) Orbit: solar synchronous orbit
e) Launching target year: 1991

3) Present research and development plan. The investigative research for the first land observation satellite will be done by 1978.

3. Development and Launching Schedules for Earth Observation Satellites (proposed)

Based on the development plans outlined in 2 above, the development and launching schedule of land observation satellites is given in Figure 3. Table 7 shows the proposed long-term development schedule for the basic associated technology.

4. Development Plans for the First Marine Observation Satellite (MOS-1) /61

4.1. Basic policy for development

Use will be made of the technical achievements made by the space development project groups as far as possible, and development of satellite equipment will proceed with the close cooperation of all research organs. As far as possible, use will be made of domestic technology and domestically-produced parts.

4.2. The target period for development

In 1978, the research and development done in 1977 will be continued, and preliminary plans for a satellite made. At the same time, research and development on earth observation equipment will proceed.

The marine observation satellite -1 (MOS-1) will observe oceanic phenomena, concentrating on the color of the sea surface and temperature, but at the same time it will be used to establish technology common to earth observation satellites. The goal is to launch MOS-1 from Tanegashima Space Center in 1983.

4.3. Outline of systems development /62

1. Earth observation equipment. The earth observation satellite launched in 1983 will carry the following observation equipment:

1) Visible-infrared radiometer (ground-resolving power: 50 m, 4 bands in the near visible-infrared field)
2) Visible thermal infrared radiometer (ground resolving power: 1 km, 1 band of visible, 3 bands of thermal infrared)

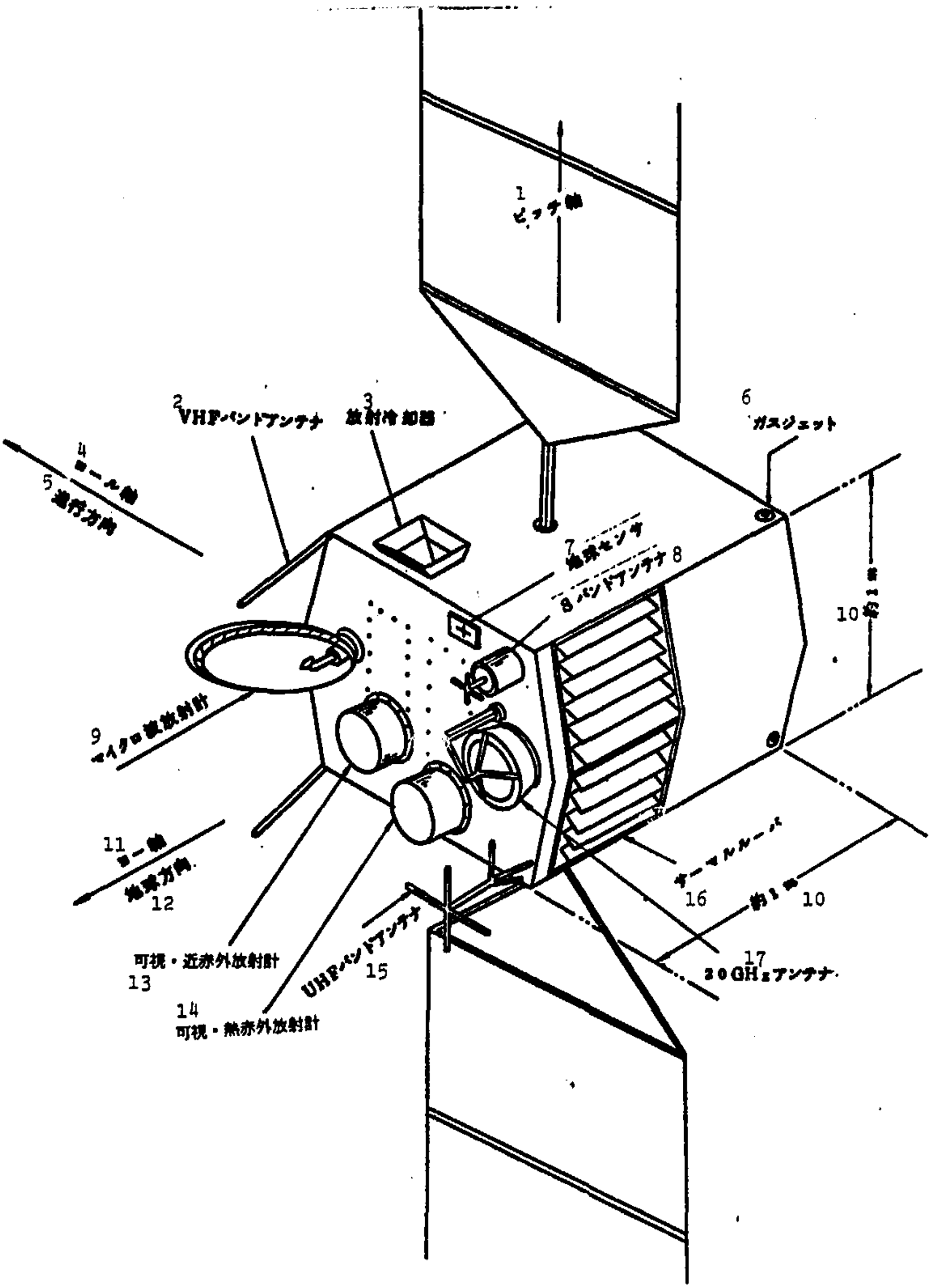


Fig. 4. Outline drawing of satellite

Key: 1. Pitch axis 2. VHF band antenna 3. Radiation cooler 4. Roll axis 5. Direction of movement 6. Gas jet 7. Earth sensor 8. S-band antenna 9. Microwave radiometer 10. About 1 m 11. Main axis 12. Direction of earth 13. Visible-near infrared radiometer 14. Visible-thermal infrared radiometer 15. UHF band antenna 16. Thermal lubbers 17. 20 GHz antenna

3) Microwave scatter meter (two frequencies of 2.3 GHz and 3.1 GHz)

2. Structure of systems and performance factors

1) Shape: box-shaped with solar cell paddles deployed in orbit (Fig. 4)
2) Weight: 600 kg
3) Orbit: medium-high circular orbit
4) Altitude control: triaxial altitude control /63
5) Launch rocket: N rocket

4.4. Development schedule

Earth observation development schedules are shown in Table 7.

V. Plans for the Development and Installation of Japan's Ground Reception and Processing Stations /69

1. Outline of Japan's Ground Reception and Processing System

An outline of the structure of the remote sensing data reception and processing system is given below (see Figure 5).

2. Development and Installation Schedule

Continuing from 1977, the goal is to complete development and installation by the end of 1978 (see Table 7).

The system as shown by Figure 5 is made up of four sub-systems: /73 the reception sub-system, the recording sub-system, the processing sub-system and the photograph-processing sub-system. The major functions of the four sub-systems are as follows.

i) The reception sub-system. This subsystem is made up of the antenna, the receiving equipment, and the tracking equipment. It receives data transmitted by LANDSAT's band from the multispectrum radiometer (MSS), the return beam videcon (RBV) camera, and telemetry concerning satellite housekeeping and attitude, recovers the data and transmits it to the recording sub-system.

ii) The recording sub-system. The recording sub-system is made up of pre-processing equipment, quick-look equipment, and recording reproduction equipment. The major function of the recording sub-system is monitoring receiving conditions with "quick-look" /74 (QL) equipment capable of presenting MSS and RBV data as images in real time, while simultaneously preparing a recorded high-density magnetic tape (HDDT) of information concerning MSS, RBV, and camera video signals and satellite housekeeping and attitude - which is input from rough-process (bulk process), prepared 70 mm black and white film and the reception sub-system.

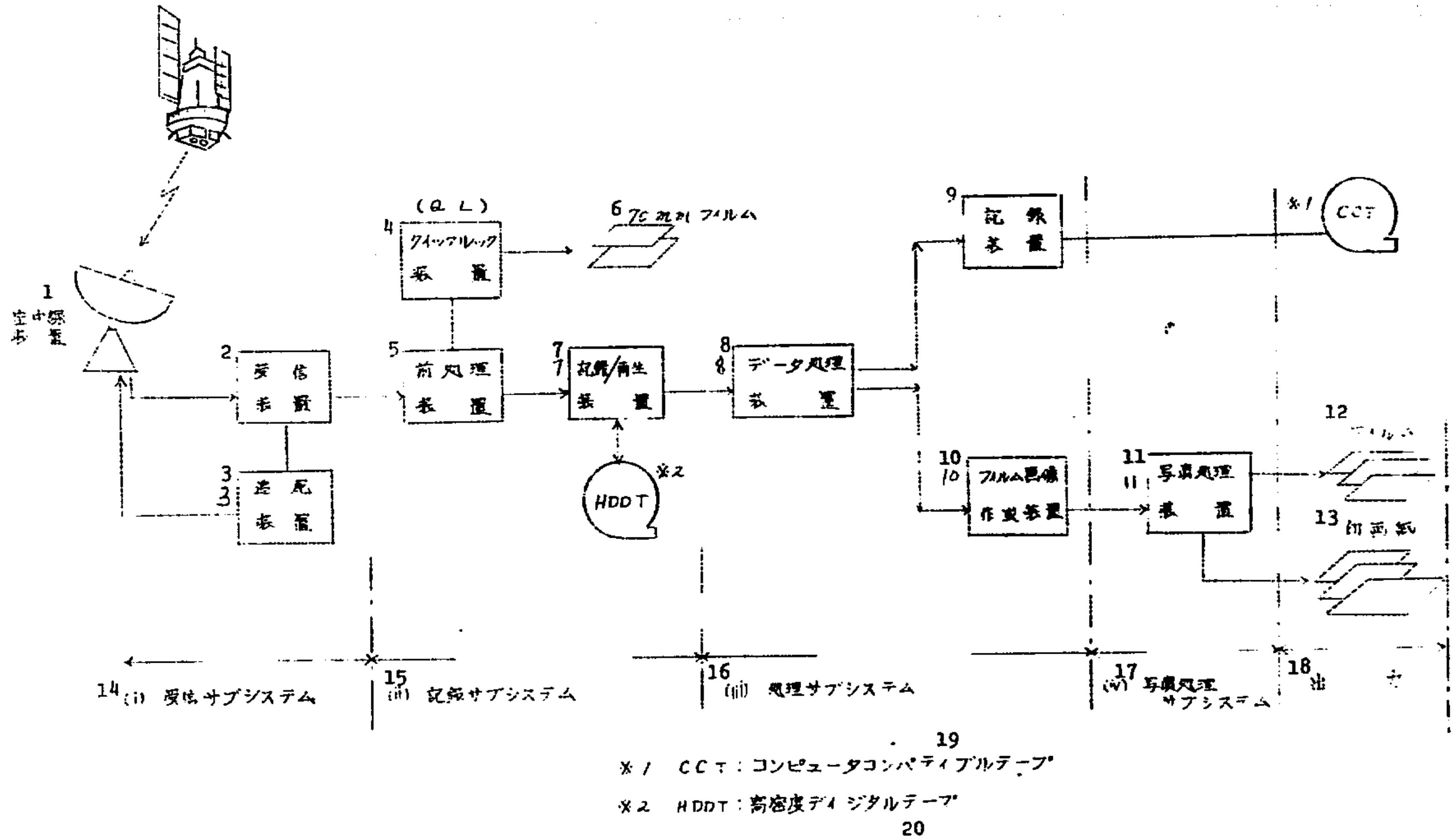


Fig. 5. Earth observation data reception, recording, and processing systems

Key: 1. Antenna 2. Receiving equipment 3. Tracking equipment 4. " uick-look" equipment 7. Recording and reproduction equipment 8. Data processing equipment 9. Recording equipment 10. Film preparation equipment 11. Photograph-processing equipment 12. Film 13. Photograph printing paper 14. Reception sub-system 15. Recording sub-system 16. Processing sub-system 17. Photograph-processing sub-system 18. Output 19. CCT: computer-compatible tape 20. HDDT: High-density digital tape

iii) The processing sub-system. The processing sub-system consists of data processing equipment, recording equipment, and film preparation equipment.

This sub-system, after correcting radiometer and geometrical distortion in the HDDT raw input data, prepares a computer-compatible tape (CCT) capable of being input to an ordinary computer. 70 mm film is also prepared by means of film preparation equipment. /75

iv) Photograph-processing sub-system. The photograph-processing sub-system prepares photographs for interpretive use from 70 mm film which is input from the film preparation equipment.

3. Outline of the Functions of the Ground Reception and Processing System

1) The reception sub-system
   a) Antenna: diameter 10 m, X-Y mounted Cassegrain type
   b) Tracking equipment: automatic program. Three automatically-programmed tracking modes
   c) Receiving equipment: frequencies (2265.6 MHz (MSS data), 2229.5 MHz (RBV data), 2287.5 MHz (housekeeping and attitude data) /76
   Noise temperature 55°K

2) Recording sub-system:
   a) Preprocessing equipment: input signal 15.06 MbpS, PCM data (MSS data); 3.2 MHz analogue video (RBV data), 1 KbpS PCM data (housekeeping and attitude data)
   Output signal: (1) Signal for use with quick-look equipment
   (2) Recording/reproduction equipment signal
   b) Recording/reproduction equipment:
   For MSS: 10-track SISO (serial in and out)
   For RBV use: 20-track SISO (serial in and out)
   For housekeeping data use: 1-track
   For time use: 1-track
   c) Quick-look equipment: (output) CRT presentation, photography by 70 mm film

3) Processing sub-system
   a) Data-processing equipment:
   Radiation accuracy: 1 quantization level
   Geometrical accuracy: 80 m
   Processing capacity: about 10 scenes/day
   b) Recording equipment: (output) CCT
   Recording density: 800 bpi and 1600 bpi
   Recording method: NRZ-1 and PE
   Bit rate: 200 KB/sec

/67-68

TABLE 8. DEVELOPMENT SCHEDULE FOR EARTH OBSERVATION SATELLITES

Heading	1976	1977 52	1978 53	1979 54	1980 55	1981 56	1982 57	1983 58	1984 59
Development of earth observation satellites		Concept design	Preliminary design	Basic design	Detailed design EM	PM	FM	Earth observation satellite	Launch (planned)
Research on earth observation equipment: methods and specifications	Study of methods and specifications	Parts, trial fabrication & testing	Trial fabrication EM	Testing	PM	FM			
Development of experimental technical satellite			(FM)	(PFM)	FM	Launch ETS-II			
Development of ground reception and processing installations		Designing and trial manufacture	testing	Research on the use of LANDSAT data (feedback for the development of satellites and ground systems)			Design improvement, manufacture	Experiments	Data reception
Notes (launching plans for NASA earth observation satellites)	LANDSAT-2 (50.1 launched Jan. 1975)	LANDFC will be launched March, 1978 (53.3)	SEASTA-A (53.5 will be launched May, 1978)						

c) Film preparation equipment: laser-beam recorder for both black and white film, 70 mm film
d) Photograph-processing sub-system (output): 70 mm black and white film, 240 mm black and white film, 70 mm black and white prints, 240 mm black /79 and white prints, 70 mm color film, 240 mm color film, 70 mm color prints, and 240 mm color prints

4. Development and Installation Schedule

The goal is completion of development and installation of reception and processing installations for the reception and processing installations for the reception and processing of LANDSAT data in 1978 (see Table 8).

(Addendum): Analysis for Utilization /80

In addition to the above, there is another system of analysis for utilization of data. Since this system conducts analysis by very detailed methods for utilization in various fields, a general discussion cannot be given here. In terms of ordinary equipment and photograph preparation, the following can be said. When the observation data is received as monochrome film by wave length, the film can be overlapped with a viewer, the appropriate color added, and analyzed visually.

Or, the information from film can be fed into a computer using flying spot equipment, and analyzed by computer the same way that data received in the form of CCT (computer-compatible tape) are used.

The principal advantages of analyzing by computer are as follows.

1. Highly accurate analytical research is possible, because the information is digital, and the accuracy is not lowered by reproduction or synthesis.
2. By using computer software, automatic analysis, and analysis for which complicated conversions are necessary, are /81 possible.
3. Analytical research is made easier by enhancement and enlargement of the object with the use of computer-related equipment (for example CRT).

Using this system, the user can obtain information useful to his own special field.